The NOAA Unique CrIS ATMS Processing System (NUCAPS) : Algorithm Readiness Review

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(1) I&M System Group
(2) NOAA/NESDIS/STAR

Outline

- The NOAA Unique CrIS/ATMS Processing System (NUCAPS) is an inversion algorithm, heritage of the AIRS Science Team and NOAA IASI inversion algorithm (same code, same underlying spectroscopy) and applied to the CrIS and ATMS Sounding System data.
  - » Inputs: CrIS and ATMS radiance
  - » Outputs: Temperature, Water Vapor, cloud cleared radiance, trace gases, cloud parameters
- This presentation: a review of the algorithm readiness for transition into operations (January 2013).

- Outline of the validation results presented here:
  - » Temperature, water vapor , ozone
    - – global validation versus collocated ECMWF and AVN analyses.
    - – AIRS version 6 and AIRS version “5.9”
    - – Tropical, Mid-Latitude, Polar; Back up slides: Day/Night; Ocean/Land regimes

- Results show:
  - » **After only one year in orbit, NUCAPS T, q and O3 performance is already comparable to AIRS v6 and AIRS v5.9 over all geophysical regimes.**

NUCAPS inversion algorithm

- NUCAPS retrieval algorithm sequential steps:
  - **1) Microwave retrieval module (from tuned radiances)**
    - cloud liquid water flags
    - surface classification
    - Temperature and moisture retrievals (not used)
  - **2) Fast eigenvector regression first guess retrieval**
  - **3) IR cloud clearing module**
  - **4) Fast eigenvector regression first guess retrieval**
  - **5) Physical retrieval module (from tuned radiances, channel selection)**
    - Surface emissivity, surface temperature,
    - T, H2O and trace gases vertical profiles
    - OLR, cloud fraction and pressure

ATMS and CrIS Brightness Temperature Tuning

- A large category of inversion algorithms relies on least square residual minimizations of observed brightness temperature and brightness temperatures computed from first guess profiles.
- In these algorithms, generally referred to as "physical", radiative transfer calculations are performed by mean of theoretical forward models and there is a need for identifying and removing those components of the residuals arising from:
  - (1) forward model errors: systematic and profile – dependent ;
  - (2) measurement errors : radiometric calibration, thermal emission from parts of the space-craft, and antenna side lobe effects (for the mw case only);
  - (3) instrumental noise;

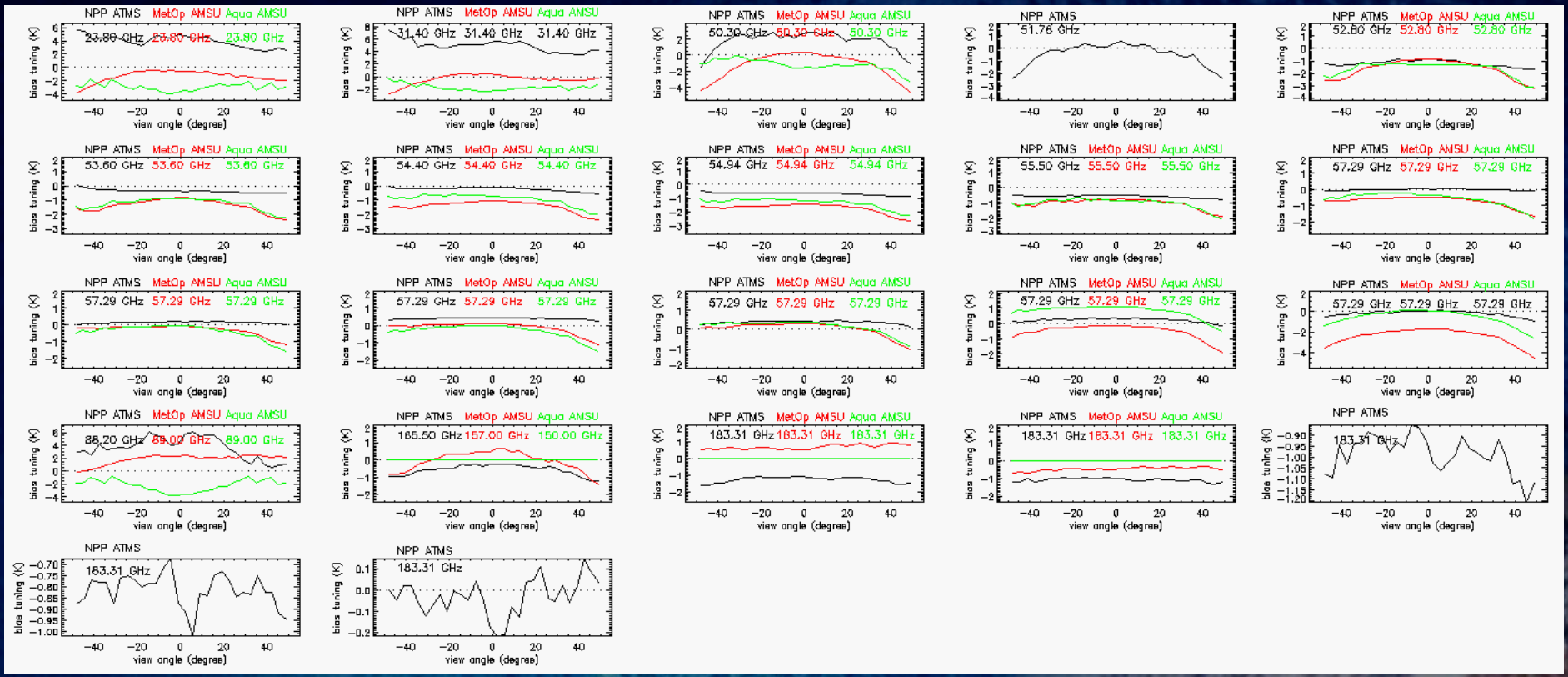
- **Significance:** This process, commonly referred to as *brightness temperature tuning*, is fundamental to achieve retrieval performance accuracy, in that it removes artificial systematic biases that could be otherwise ascribed to atmospheric sources and, in long term applications, erroneously confused with climate signals.

- **Methodology:** using forward model computations (MIT MW forward model, SARTA IR model), a tuning coefficient set is computed as an average bias difference of a global sample of "OBS" - "CALC" computations, for each channel (and scan angle position for ATMS).

- In reality, we limit the collection of OBS-CALC samples over a restricted area of the globe which only includes ocean, clear sky, nighttime and tropical to mid-latitude cases, where the collection of correlative "truth" profiles is relatively more reliable compared to the remaining geophysical areas of the globe.

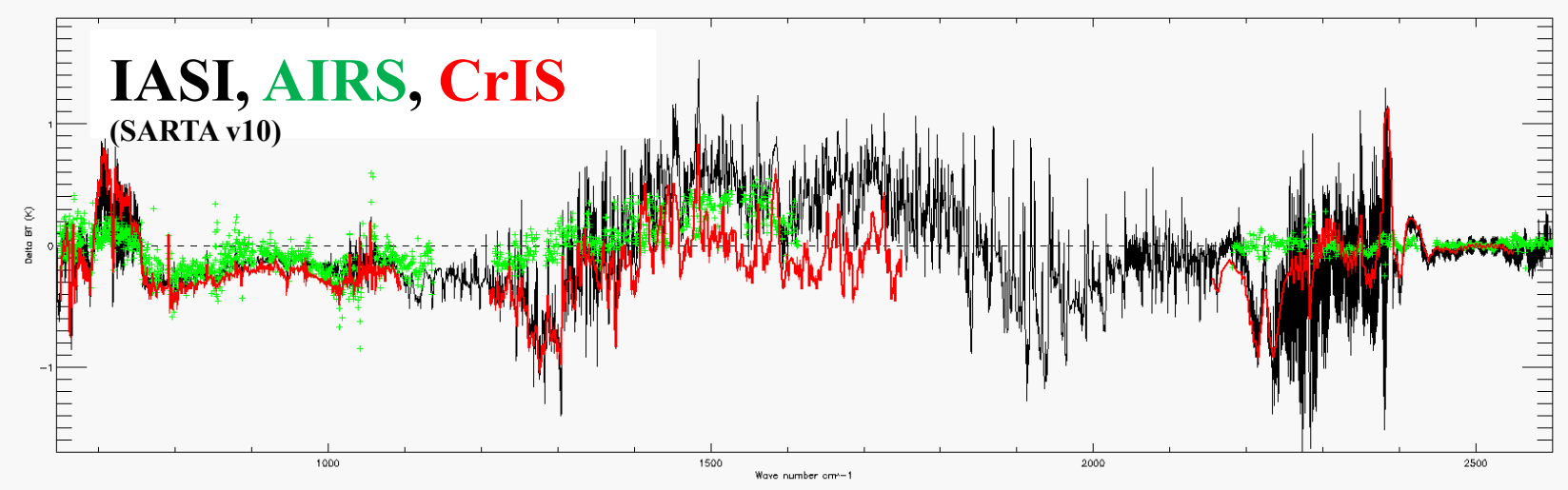
ATMS, Aqua AMSU-A, MetOp AMSU-A and MHS BT tuning comparison

(average OBS-CALC(truth); Truth employed is ECMWF analysis)



Ref.: Gambacorta et al., A methodology for computing systematic biases of top of atmosphere brightness temperature calculations. Part I: Microwave brightness temperature computations. A case study using the Advanced Technology Microwave Sounder (ATMS), 2012, in preparation.

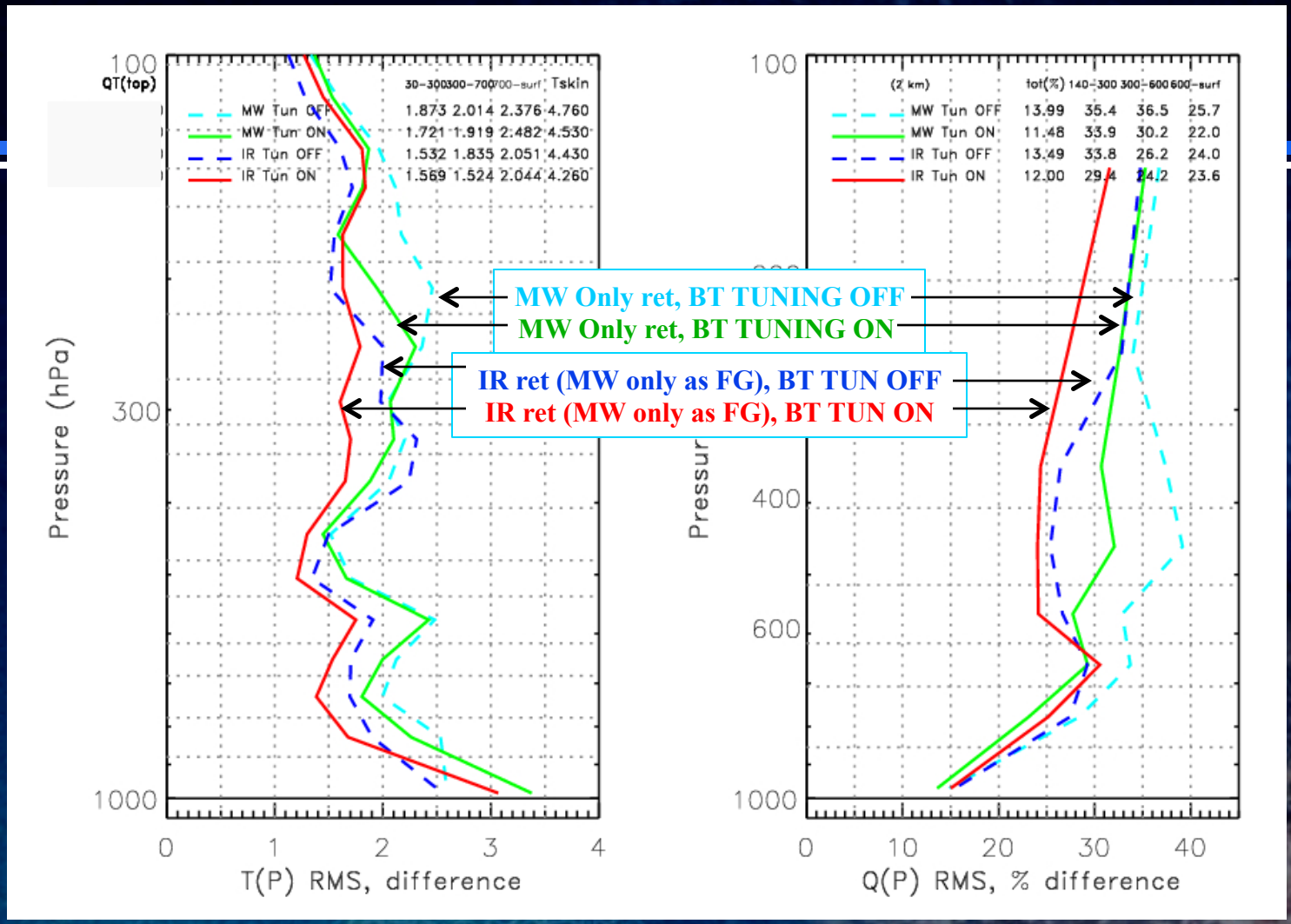
CrIS, AIRS and IASI BT tuning comparisons



- Truth employed:
  - Temperature and water vapor: ARM RAOBS for AIRS; ECMWF for IASI and CrI
  - UTLS Temperature: un-tuned retrievals
  - Trace gas climatology
- Consistent shape among tuning coefficient sets. AIRS RTA already tuned.

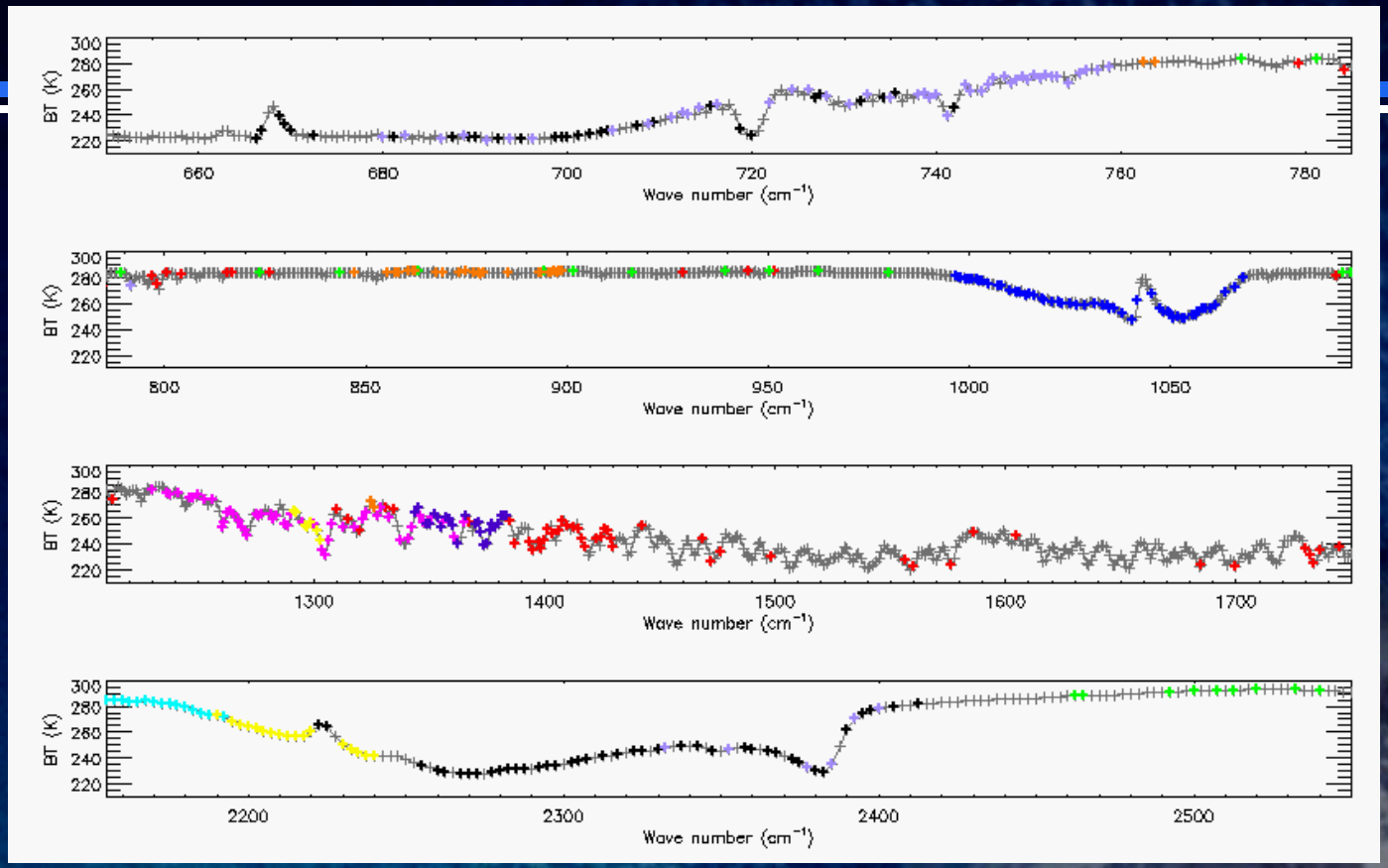
Ref.: Gambacorta et al., A methodology for computing systematic biases of top of atmosphere brightness temperature calculations. Part II: Infrared brightness temperature computations. A case study using the Cross-Track Infrared Sounder (CrIS), 2012, in preparation.

Tuning vs No Tuning retrieval impact (vs ECMWF)



- Overall BT tuning technique shows consistent improvements in T (up to 0.5K) and Q results (up to 10%)

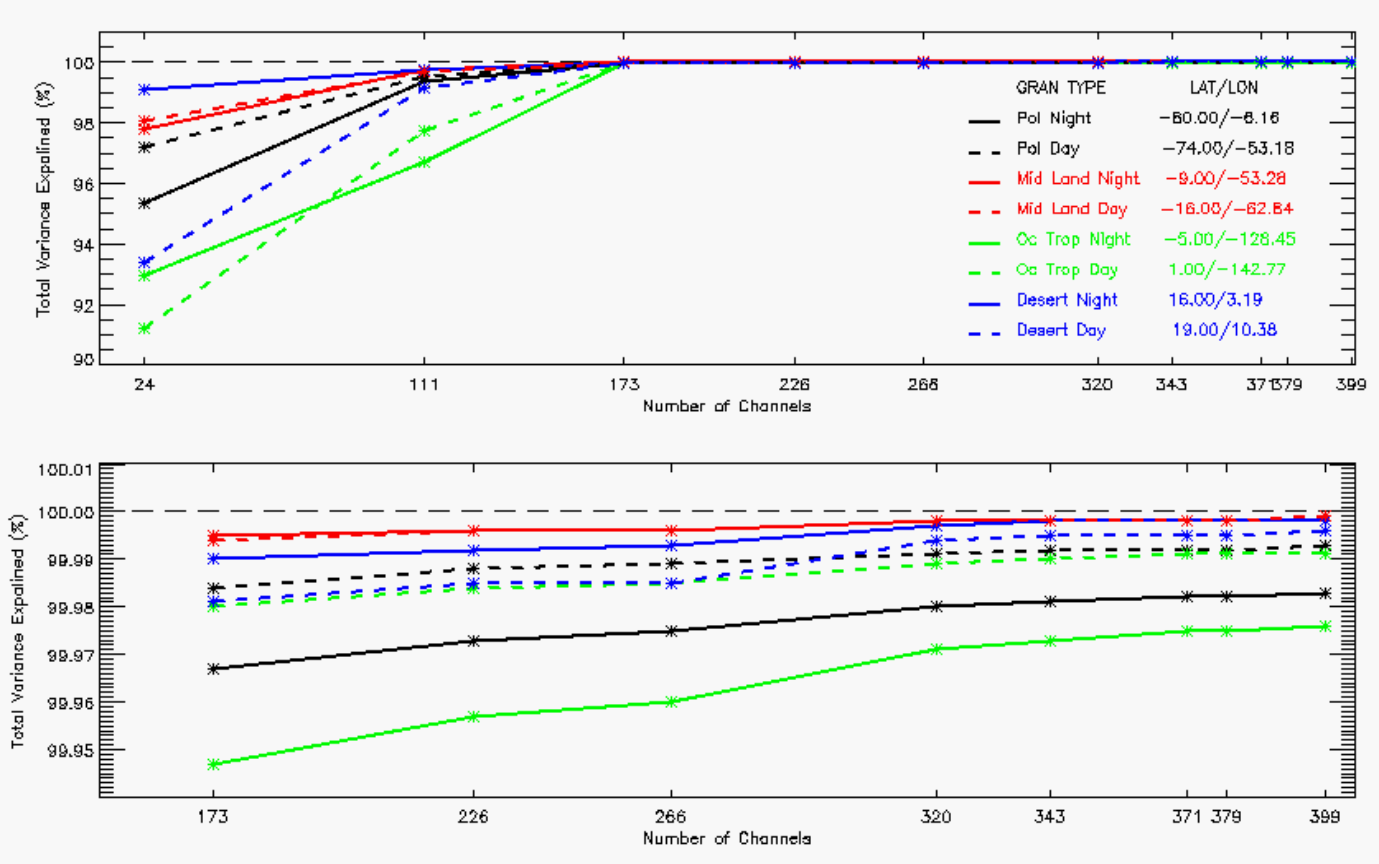
CrIS operational Channel Selection (Total # of Channels: 399)



Black crosses: temperature sounding channels; Light Purple: CO2 sounding channels; Red crosses: Water vapor sounding channels; Green crosses= surface temperature and emissivity sounding channels; orange crosses= NHO3 sounding channels; Blue crosses = ozone sounding channels; magenta cross symbols= CH4 sounding channels; Cyan crosses= CO sounding channels; Yellow crosses = N2O sounding channels; Dark Purple=SO2 sounding channels; Grey = all remaining channels.

REF: A. Gambacorta and C. Barnet, Methodology and information content of the NOAA NESDIS operational channel selection for the Cross-Track Infrared Sounder (CrIS), IEEE Transactions on Geoscience and Remote Sensing, 10.1109/TGRS.2012.2220369

Total Variance Explained



- The total explained atmospheric variance increases asymptotically by incrementally adding unique channels. The full list of 399 selected channels explains ~99.9% of the total atmospheric variance.
- First 173 channels (window, temperature and water vapor channels) already explain ~ 99% of the total atmospheric variance.

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Part II:
Retrieval Results

T, q Retrieval Statistics vs ECWMF; o3 vs AVN

NUCAPS: ECMWF trained ccr FG (dash), final RET (solid)

AIRS v5.9: ECMWF trained ccr FG (dash), final RET (solid)

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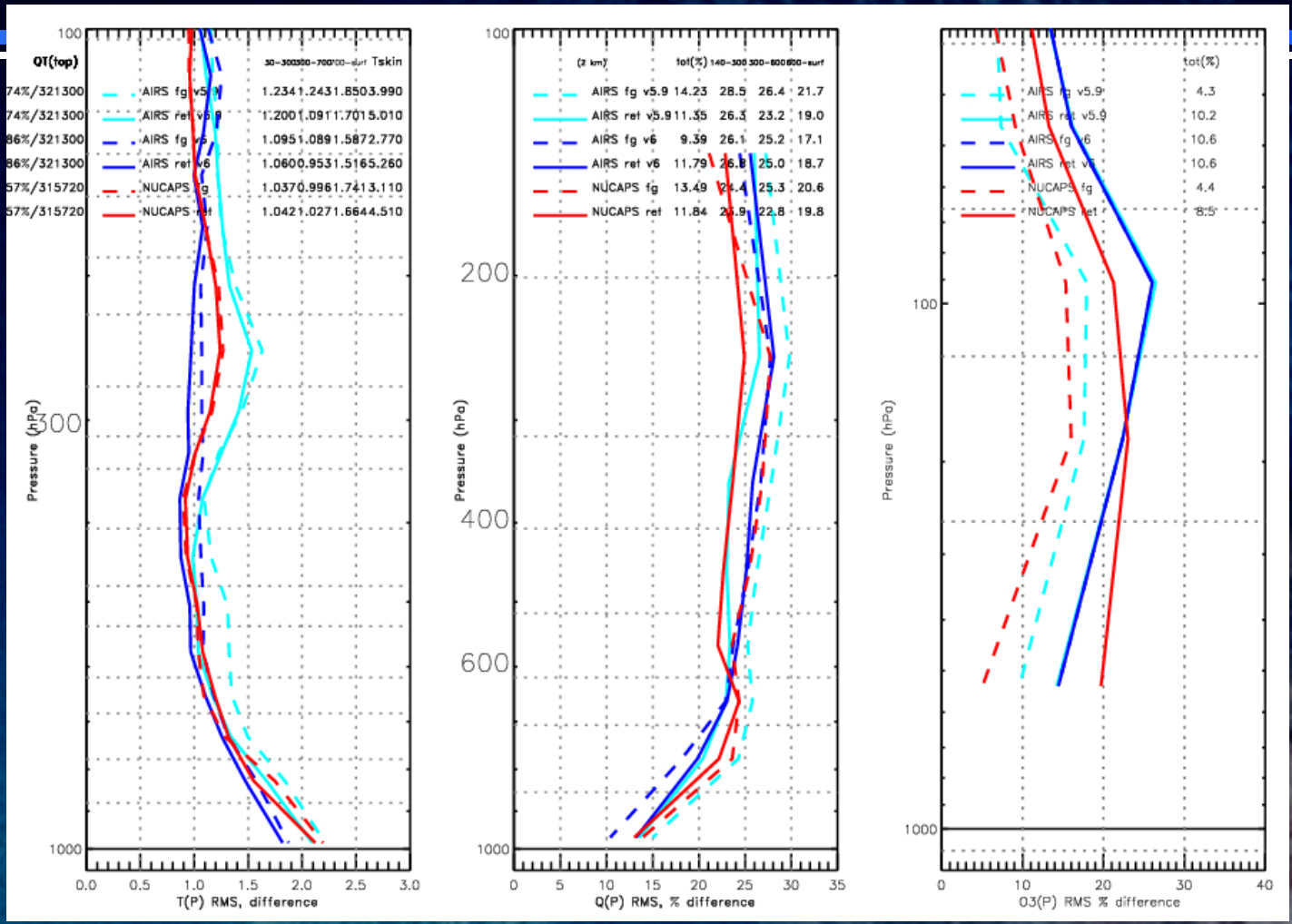
GLOBAL RMS



Significance:

- After only one year in orbit, NUCAPS T, q and O3 performance is already comparable to AIRS v6 and AIRS v5.9

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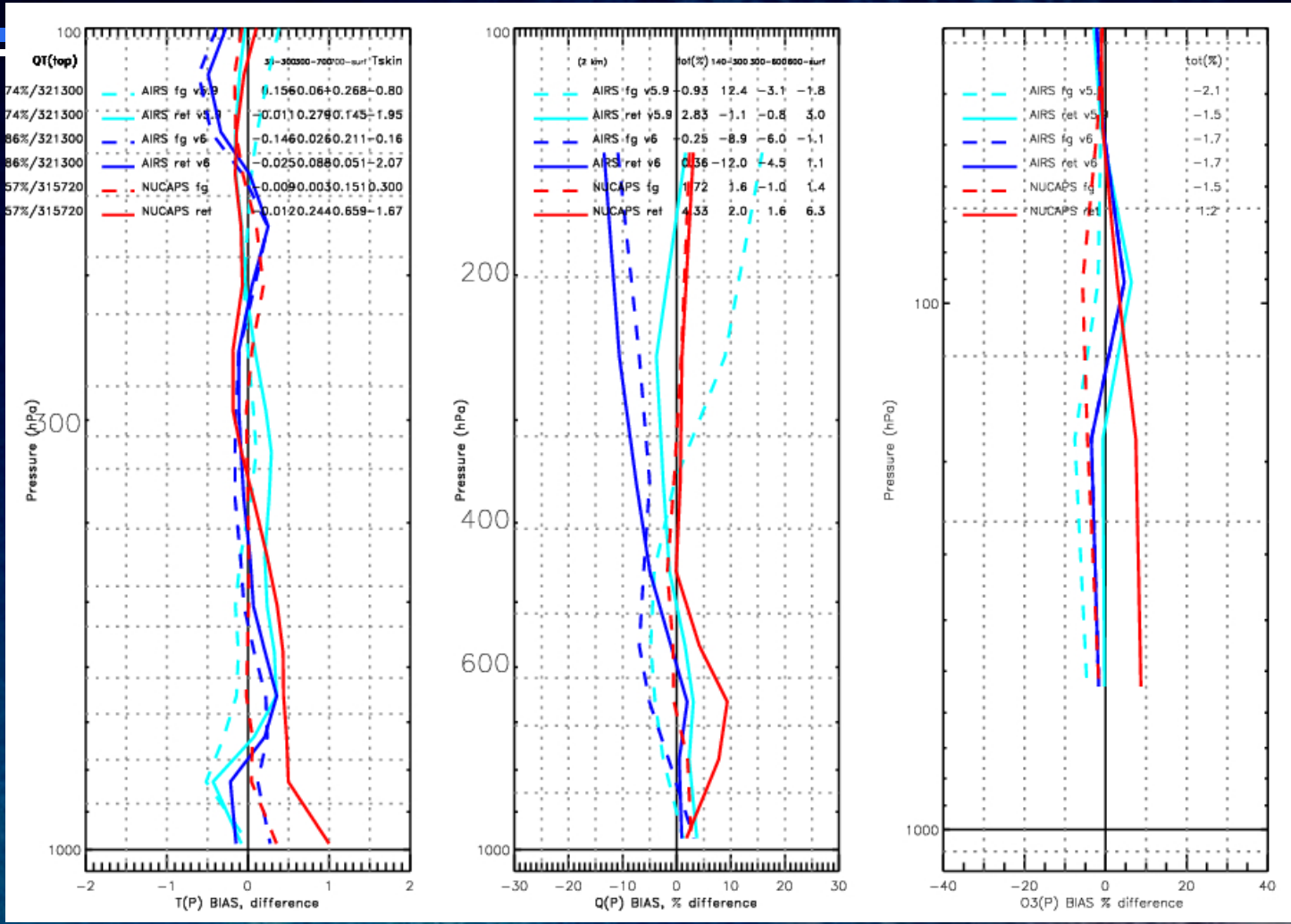

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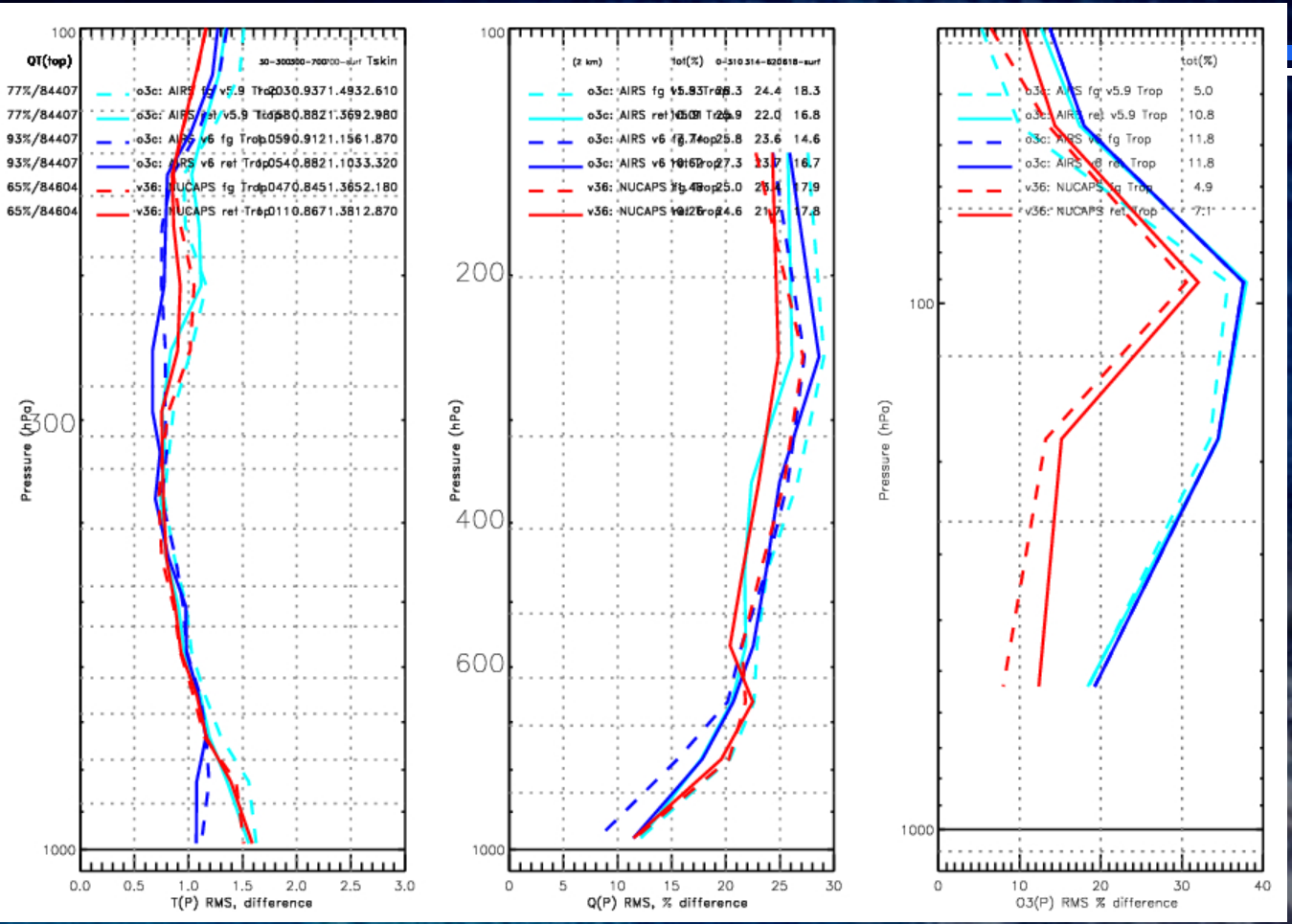
TROPICS

RMS



Possible sources of difference in the acceptance yield:

- **AIRS v6 improved surface emissivity first guess; AIRS v5.9 multi-year regression training; dedicated raob based tuning**
- **Work in progress: NUCAPS QAs optimization ; multi-seasonal regression and tuning training**

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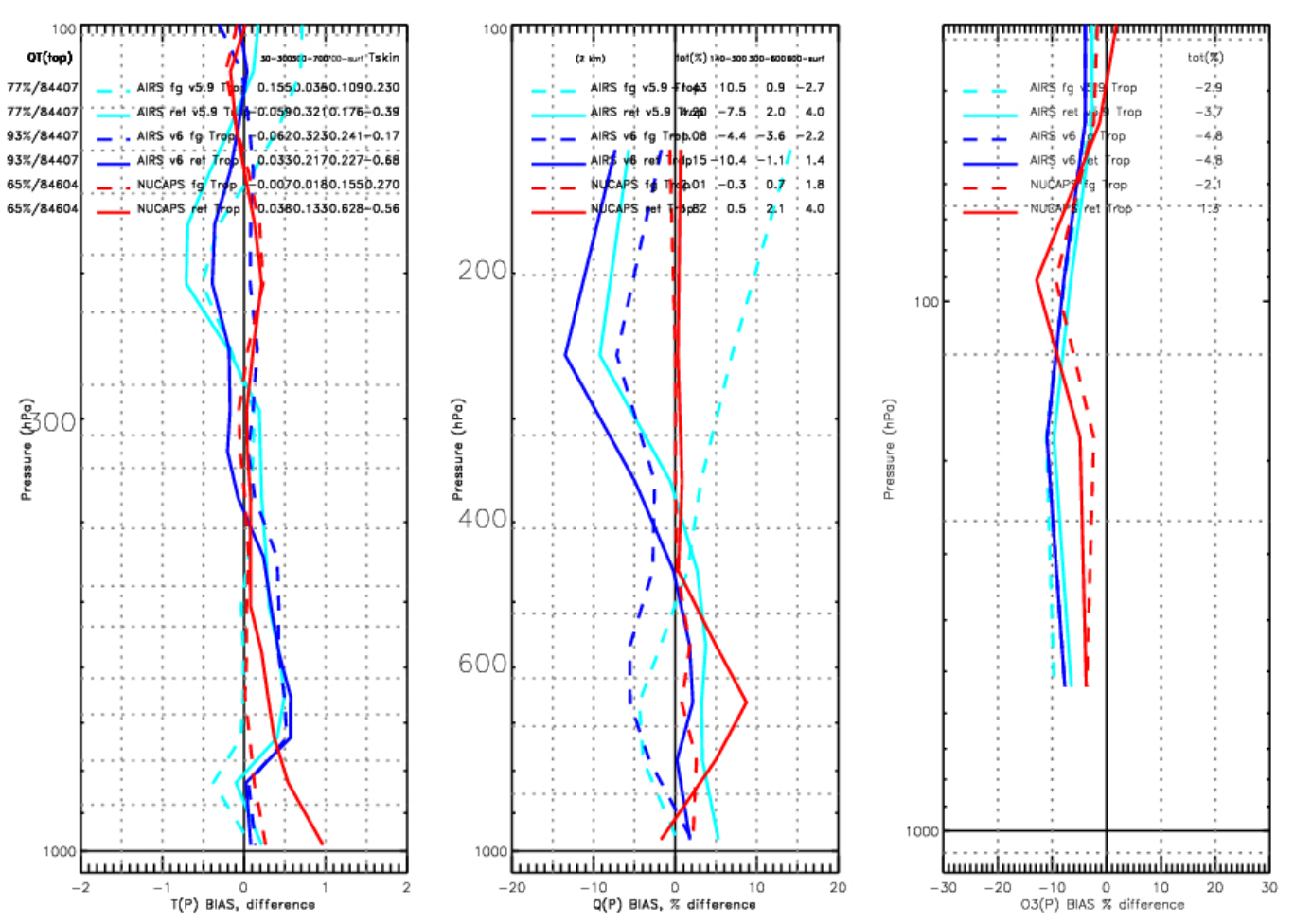

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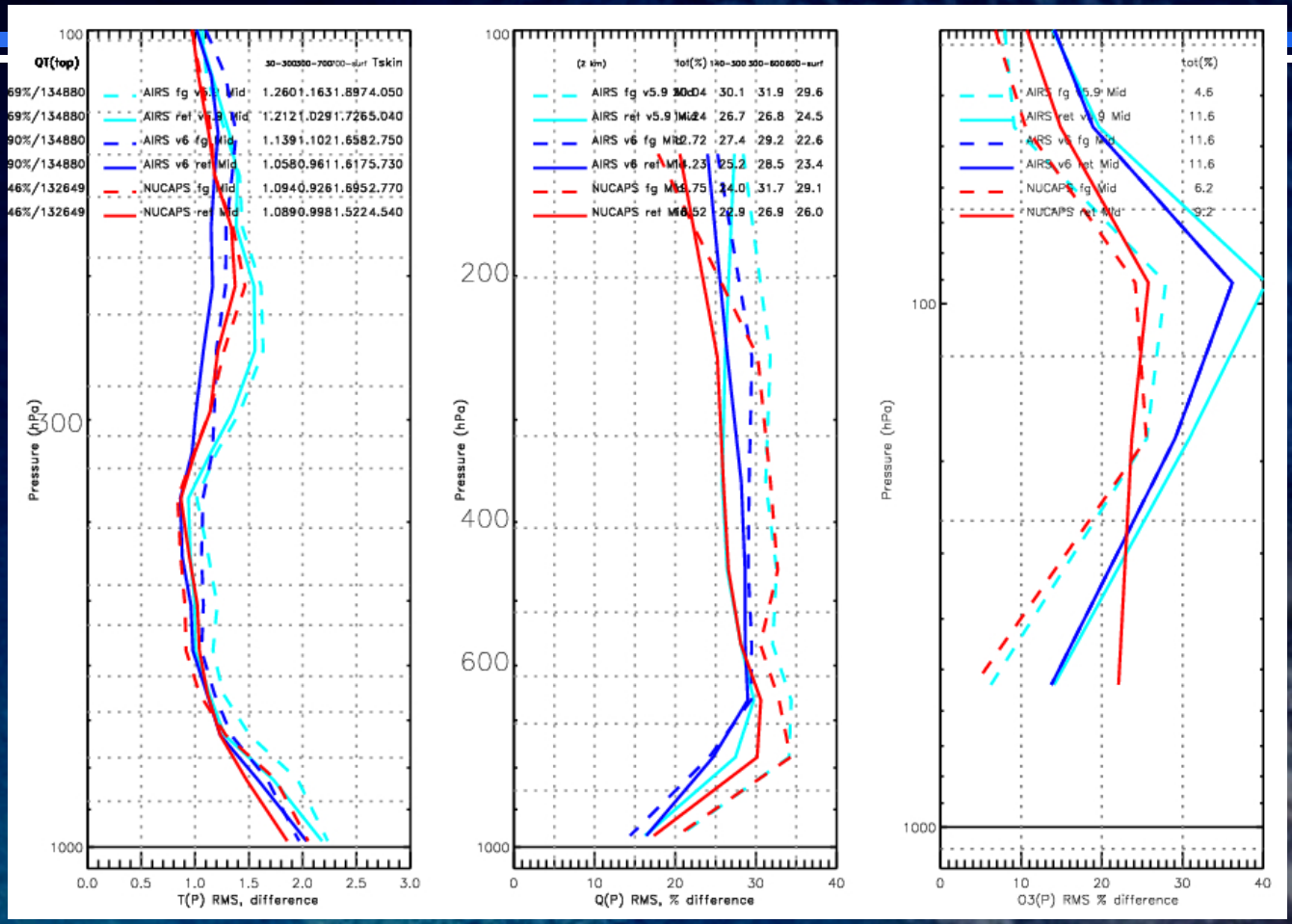
MIDLAT

RMS



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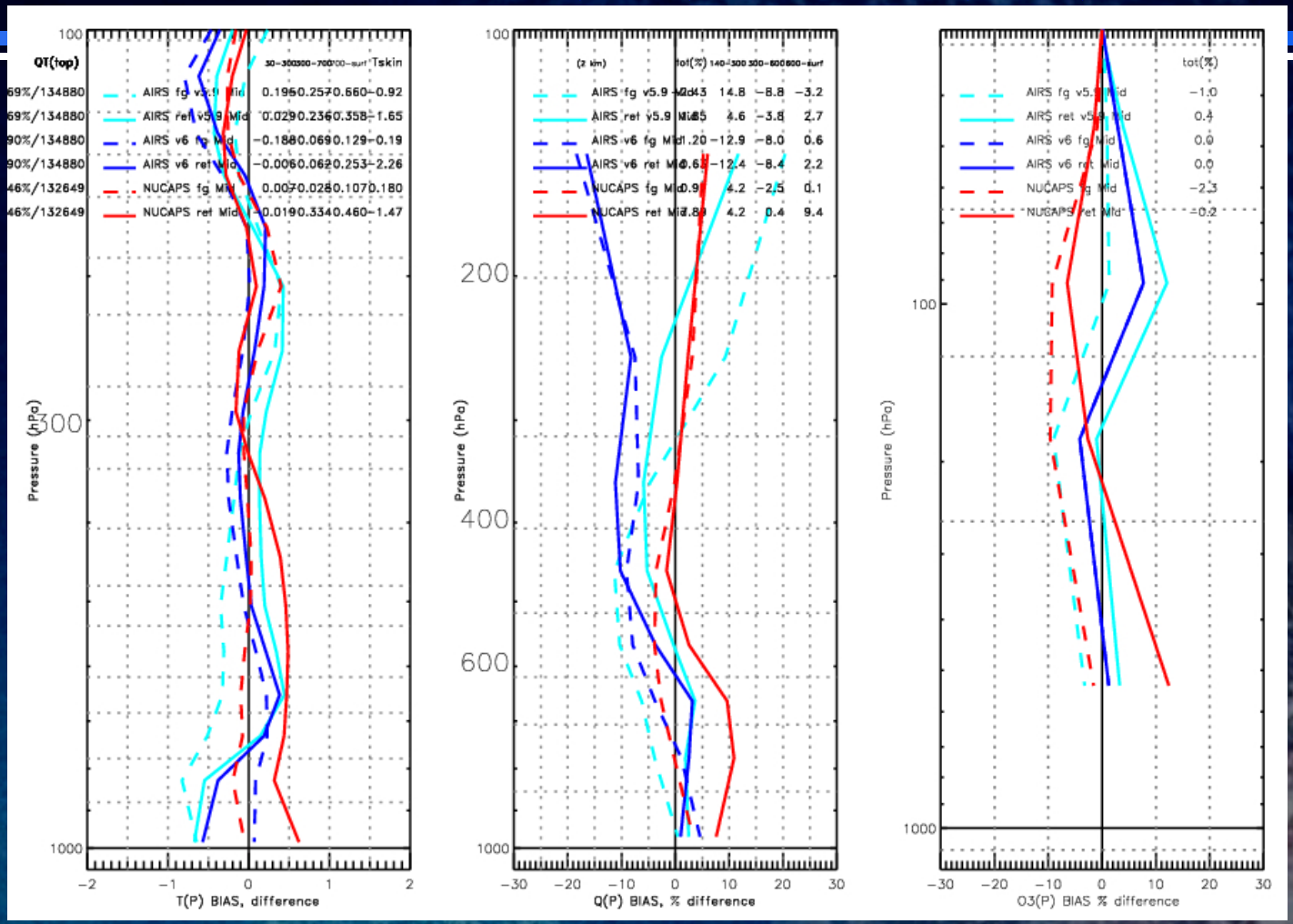

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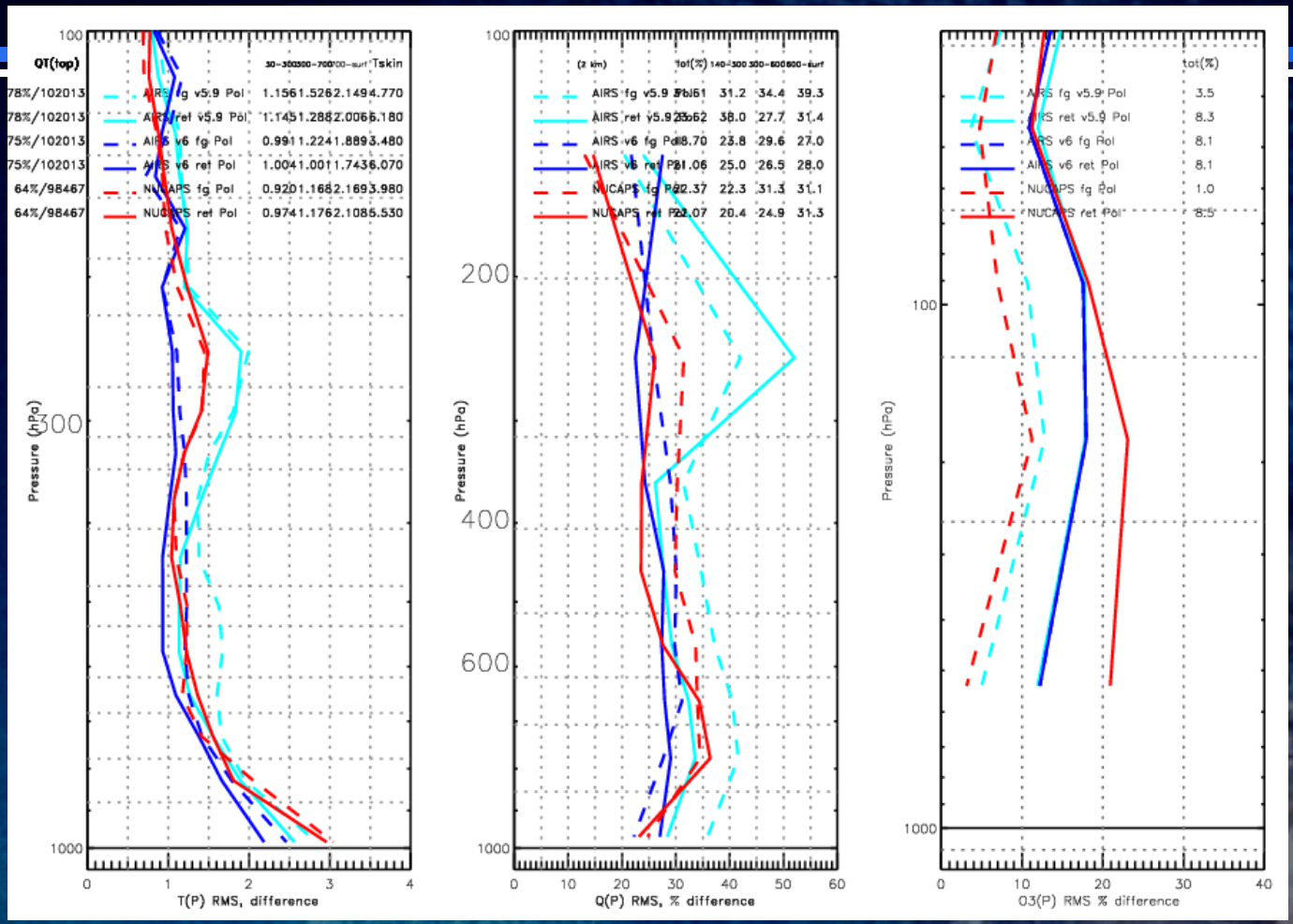
POLAR

RMS



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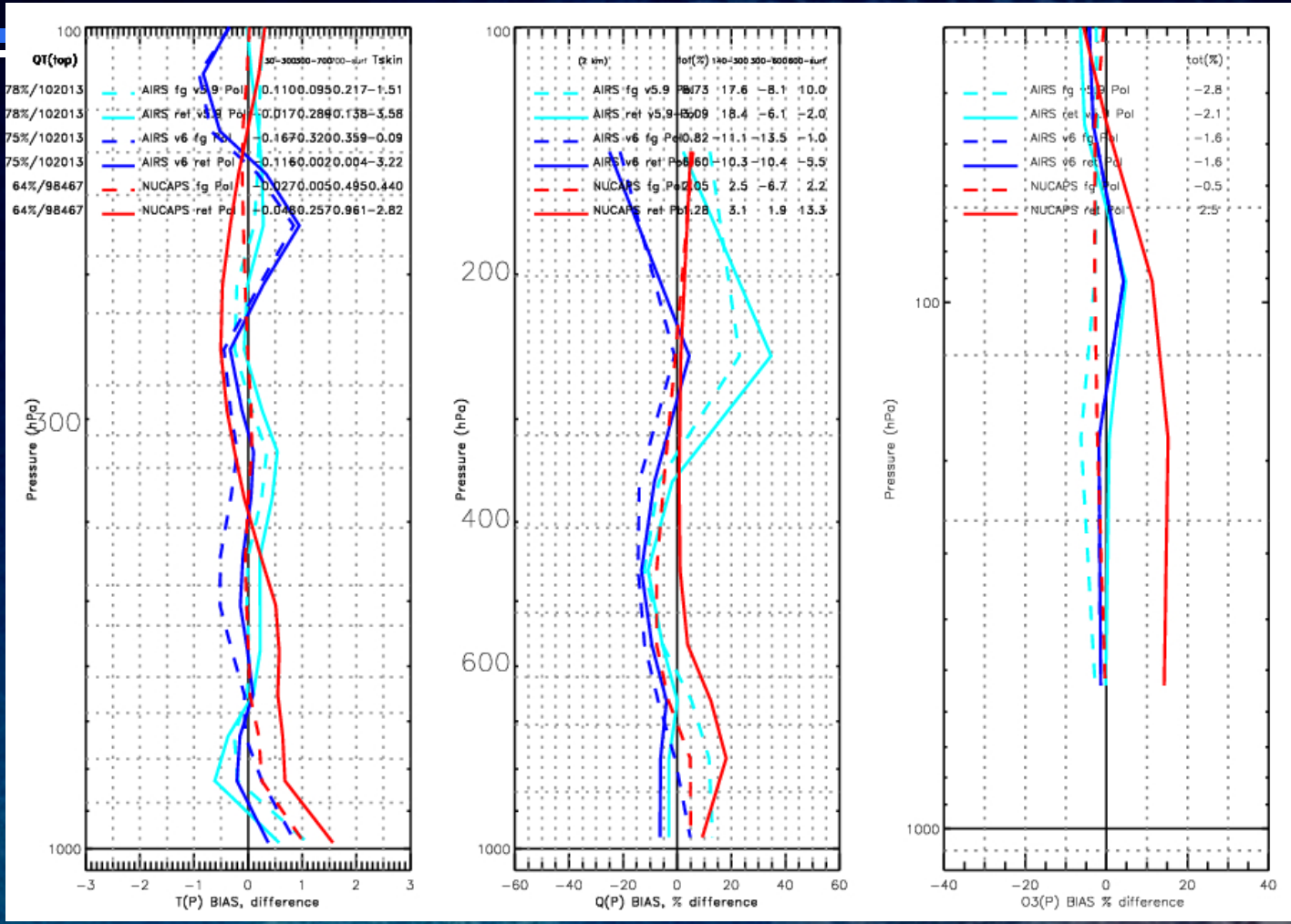
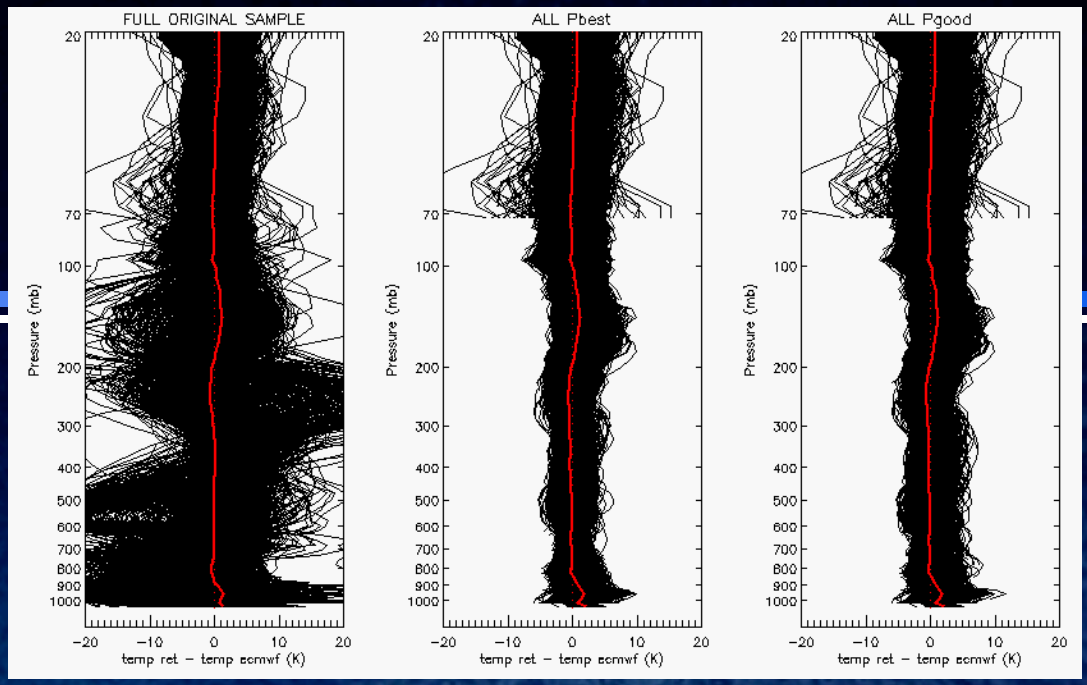


Applications

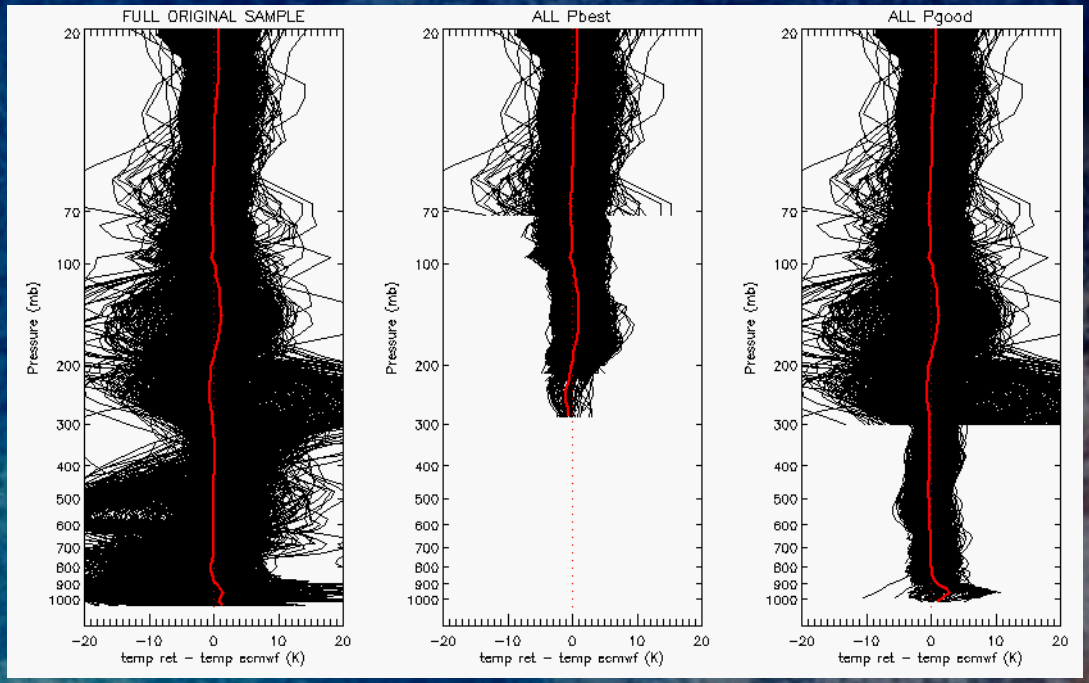
- NUCAPS channel selection world wide distributed to the full WMO/GTS user network for assimilation and retrieval applications.
- NUCAPS trace gas operational in January 2013
- NUCAPS T, moisture products operationally available in January 2013.
  - » Available to meet NWP user requests: see next slide

NWP applications

- We have implemented a technique to compute temperature and water vapor vertical quality controls for the IASI and NUCAPS retrieval algorithm.
- We resort to the AMSU and ATMS temperature retrieval respectively, and the physical cloud product retrieval information to define optimal pressure levels indicative of the retrieval quality for data assimilation purposes.
- This product is the analogous of AIRS version 5 and 6 “Pbest”, “Pgood” quality controls implemented by Susskind et al., with the main difference consisting in the choice of the retrieval quality thresholds and a physically-based determination of the sounding quality (AIRS version 5 and 6 employs ECMWF regressed predictors and fixed pressure values).
- Next slide: an overall comparison example with AIRS version 5 quality controls along with retrieval statistics over the continental US region.
-



UPPER FIGURE. Full sample differences (black curves) of temperature retrieval minus ECMWF profiles and bias statistics (red). Left: original sample. Centre: All profiles down to “NOAA Pbest”. Right: all profiles down to “NOAA Pgood”.



BOTTOM FIGURE. Same as upper figure, but using AIRS version 5 quality controls (Pbest_pge and Pgood_pge).

•We find NOAA quality indicators to be more reliable in terms of vertical acceptance yield and quality control.

Conclusions

- The NOAA Unique CrIS/ATMS Processing System (NUCAPS) is an inversion algorithm, heritage of the AIRS Science Team and NOAA IASI inversion algorithm (same code, same underlying spectroscopy) and applied to the CrIS and ATMS Sounding System data.

- We have presented a review of the algorithm readiness for transition into operations (January 2013).

- **Results:**
  - **After only one year in orbit, NUCAPS T, q and O3 performance is already comparable to AIRS v6 and AIRS v5.9 over all geophysical regimes.**
- **Applications:**
  - NUCAPS channel selection is being world wide distributed to the full WMO/ GTS user network for assimilation and retrieval applications.
  - NUCAPS temperature, moisture and race gas will become operational in January 2013
  - NUCAPS is available to meet NWP user requests.

Back up slides

NOAA Pgood Pbest tests

- **TEST 1.**
- **1.1** If the version 3 rejection quality flag indicates that both the AMSU-only and the physical retrievals have been rejected: Pbest_NOAA = Pgood_NOAA =70mb (see figure 1).
-
- **TEST 2.**
- **2.1** If the case is cloud-free, Pbest_NOAA=Pgood_NOAA = surface pressure.
- **2.2** If it is a **c**loudy case, Pbest_NOAA and Pgood_NOAA are defined by the cloud top pressure levels. (see figure 3)
- **2.3** If there is only one cloud formation, Pgood_NOAA is defined as the surface pressure. (see figure 2)
- **2.4** TEST 3 is applied to results from TEST 2.1, 2.2 and 2.3
- **TEST 3.**
- We compute the temperature difference between the AMSU-only and the physical retrieval. We determine where this difference initially becomes larger than 3K.
- **3.1** If this pressure level is higher than Pbest_NOAA, then Pbest_NOAA and Pgood_NOAA are re-set to this level.
- **3.2** If this pressure level occurs between Pbest_NOAA and Pgood_NOAA, then Pgood_NOAA is re-set to this pressure level. (see figures 2, 3, 4, 5,6)
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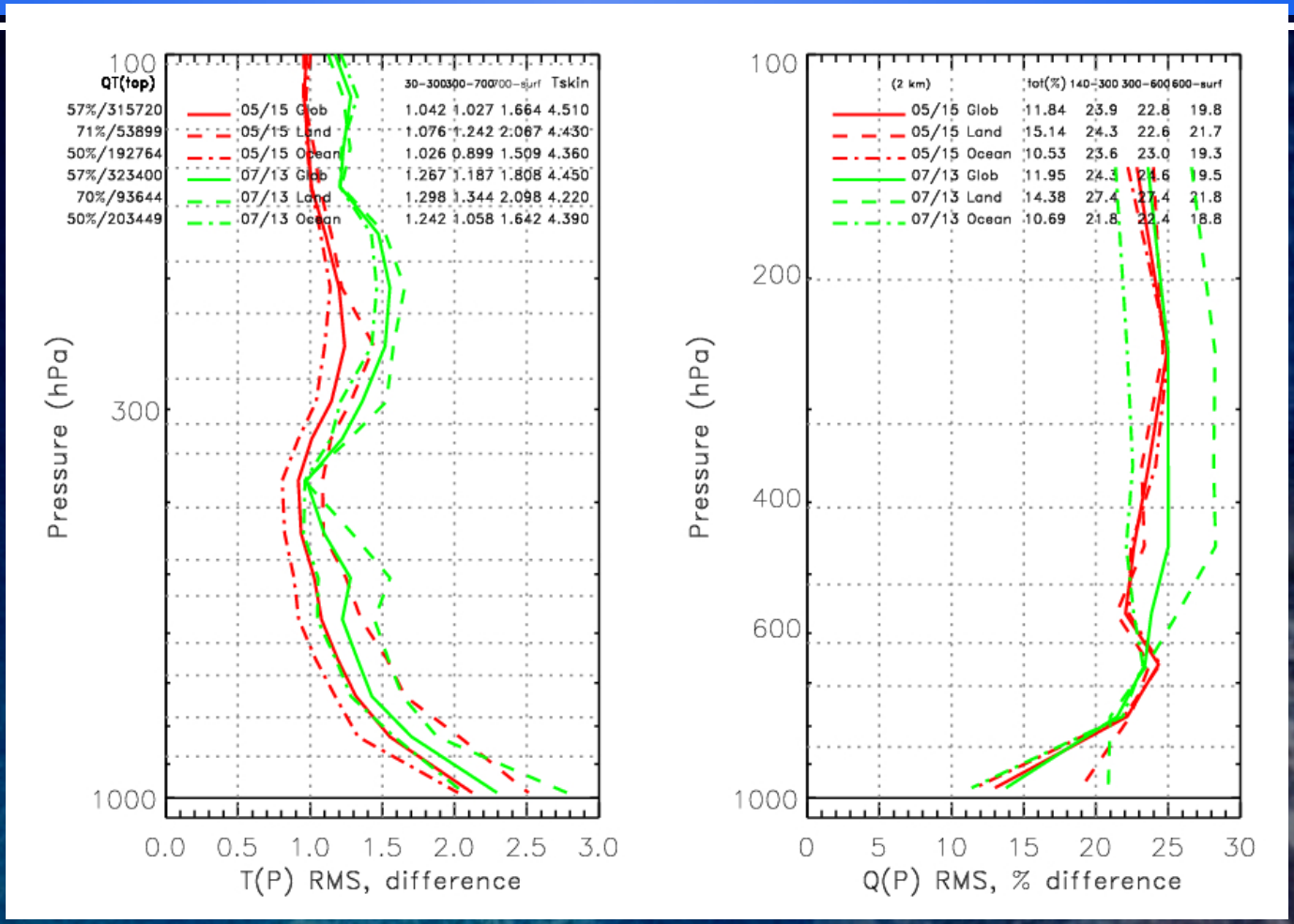
05/15 vs 07/13 focus day statistics



Significance: NUCAPS performance is stable and robust over multiple focus days

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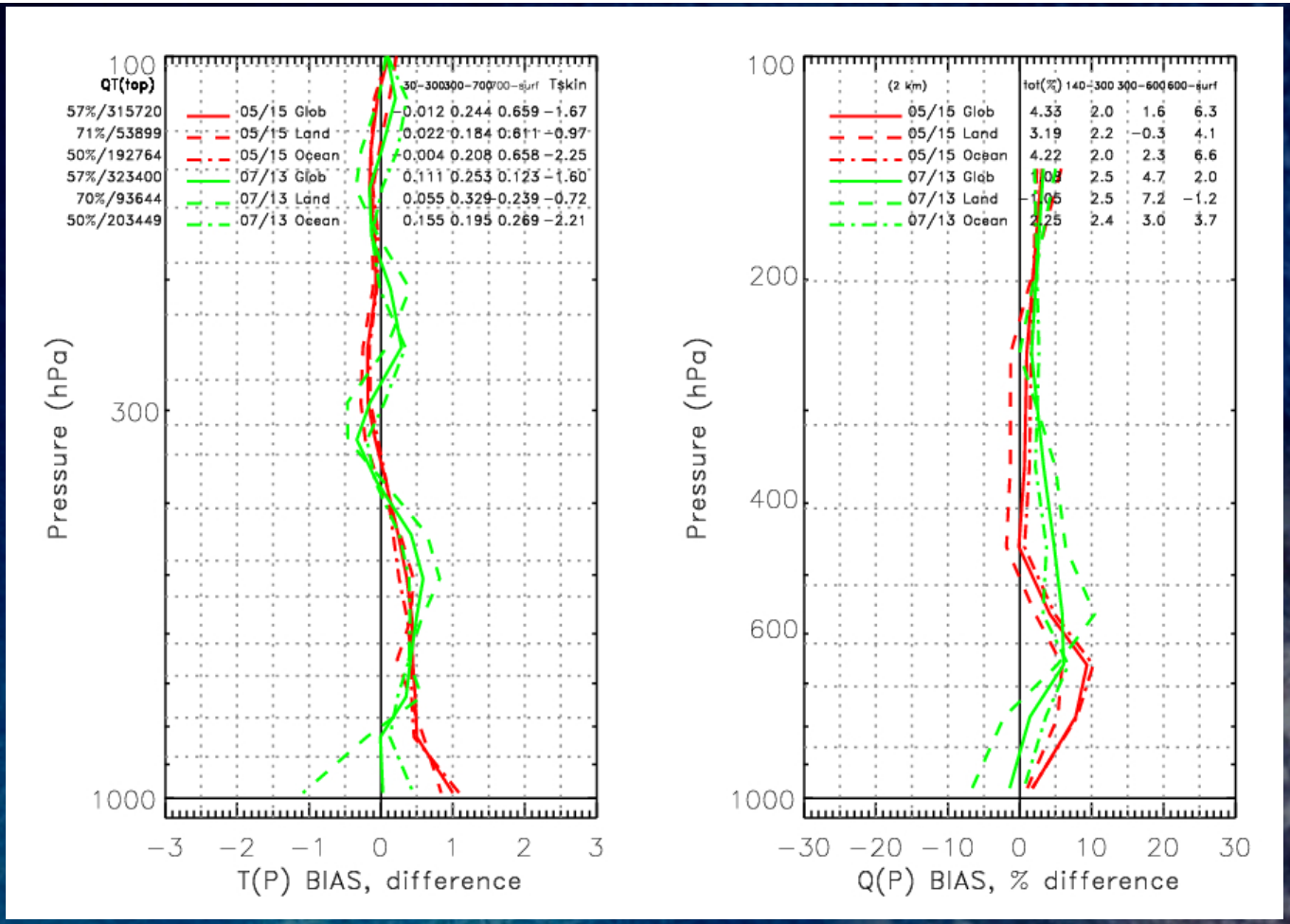

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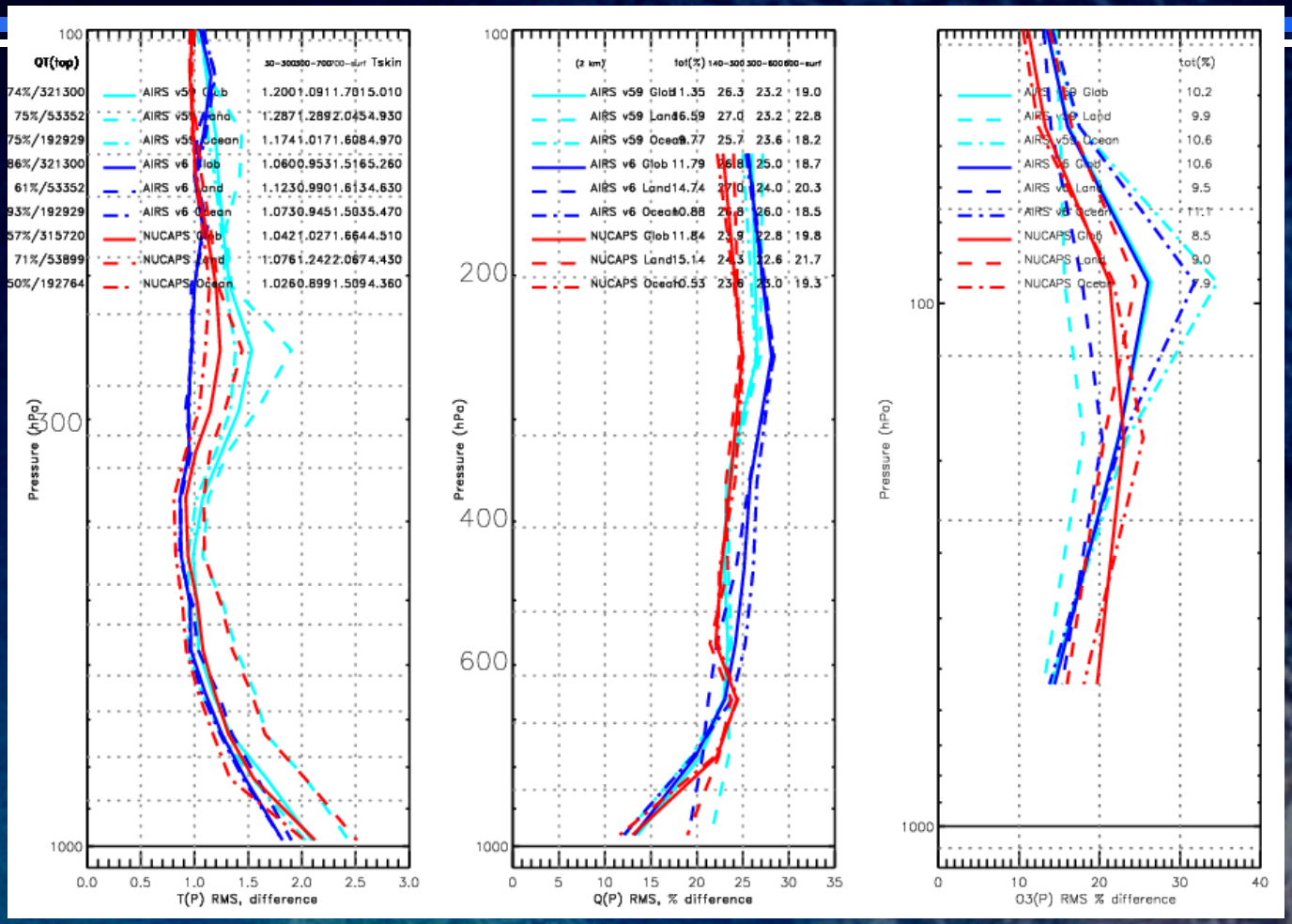
Ocean/Land

RMS



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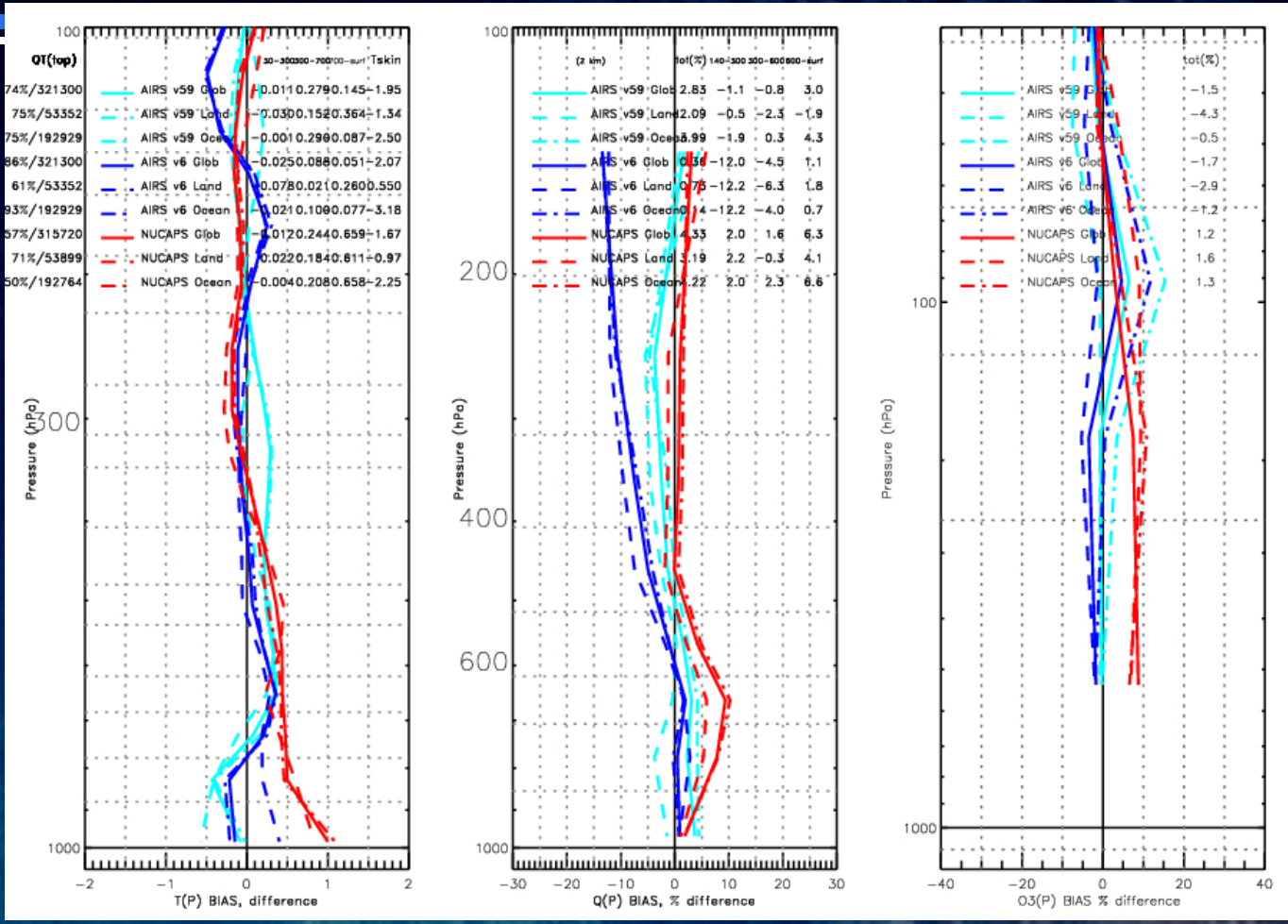

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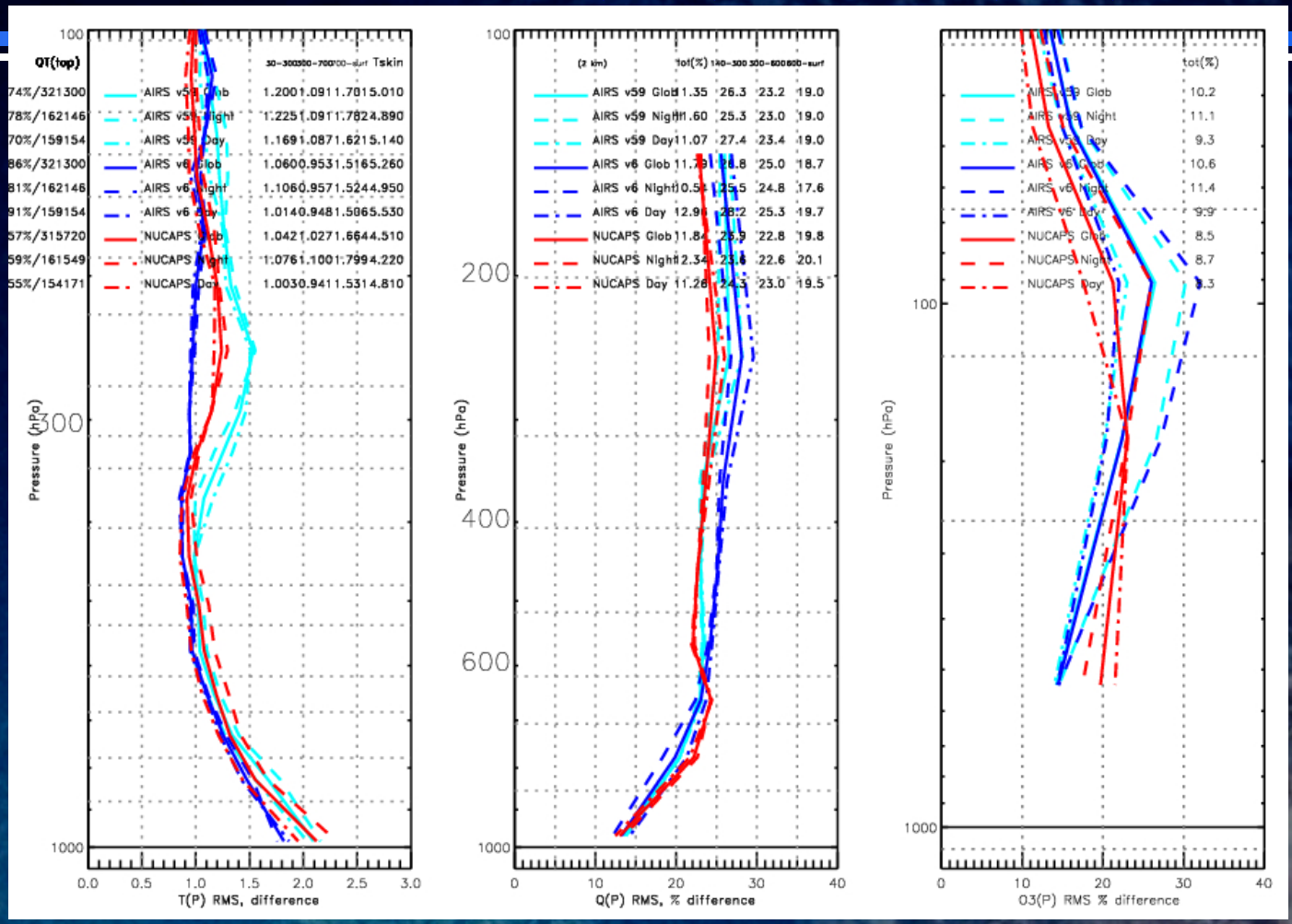

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